Title	Recent developments in seaweed diseases
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Citation	Largo, D.B. (2002). Recent developments in seaweed diseases. In: A.Q. Hurtado, N.G. Guanzon, Jr., T.R. de Castro-Mallare, & M.R.J. Luhan (Eds.) Proceedings of the National Seaweed Planning Workshop held on August 2-3, 2001, SEAFDEC Aquaculture Department, Tigbauan, Iloilo. (pp. 35-42). Tigbauan, Iloilo : SEAFDEC Aquaculture Department.
Issue Date	2002
URL	http://hdl.handle.net/10862/196

Recent Developments in Seaweed Diseases

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Most of what we know about seaweed diseases is generally focused on those affecting the *Eucheuma/Kappaphycus* seaweed, particularly the "ice-ice" disease phenomenon. However, much of our knowledge about seaweed diseases are mainly those observed in non-eucheumatoid algae, especially those cultivated for use as food in Japan, China and Korea namely *Porphyra, Gracilaria,* and *Laminaria.* These diseases vary in terms of their causative agents and manifestations. Table 1 shows the different species of cultivated seaweeds around the world that are known to be affected by microbial pathogens after being pre-disposed by certain factors.

Table 1. Diseases in commercial seaweeds caused by bacteria and other microorganisms

Host seaweed	Name of disease	Suspected causative agent	Environmental condition prior to outbreak	Author*
Porphyra tenera	white rot disease	*Beneckia (=Vibrio)*	exposure to low temperature at extended low tide period	Tsukidate 1983
Porphyra sp.	"suminori" disease	*Flavobacterium* sp.	high temperature	Kusuda et al. 1992
P. yezoensis	"anaaki" or "pin-hole disease"	*Flavobacterium* sp.	low summer temperature	Sunairi et al. 1995
Laminaria sp.	malformation disease	unidentified bacteria	high H_2S content	Uchida & Nakayama 1993
Gracilaria sp.	"rotten thallus syndrome"	*Vibrio* sp.	reduced flow rate in culture tank	Lavilla-Pitogo 1992
	"white rot"	amoeba-like organism		Correa & Flores 1995
G. conferta	"white tips disease"	unidentified bacterium	exposure to high temperature and high light intensity	Weinberger et al. 1994
G. chilensis	lesion/bleaching	agarolytic bacterial strain		Craigie 1995
Chondrus crispus	"green rot" or "green spot disease"	deep orange colored bacteria	surface wounds by mechanical or biological activities	Craigie & Correa 1996
Kappaphycus/ Eucheuma	"ice-ice"	Vibrio sp. P11, *Cytophaga* sp. P25	low salinity, low light intensity	Largo et al. 1995a, 1995b

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Andrews (1976) defined seaweed disease as "a continuing disturbance to the plant's normal structure and function such that it is altered in growth rate, appearance, or economic importance". Is this definition good enough to include the "ice-ice" disease in *Eucheuma/Kappaphycus?* "Ice-ice", as some of us are familiar with, affects not only growth but also its appearance and, possibly, carrageenan product quality. Perhaps, your definition of "ice-ice" disease is as good as this definition by Andrews.

There are two kinds of diseases in plants: infectious and non-infectious type. The former involves a transmissible infectious agent (bacteria, fungi, virus, etc.) while the latter is induced by physiogenic factors such as extremes of temperature, salinity, light intensity or pollution. Other than those in economic seaweeds, most of what is known to be diseases in macroalgae are the types that are generally less threatening to the natural seaweed population. In 1992, however, a form of an algal disease, known as coralline lethal orange disease (or CLOD), caused by an unidentified motile bacterium, consumed a large population of reef-building coralline algae in the South Pacific (Littler and Littler 1994, 1995). This phenomenon underscores the potential of a bacterial pathogen not only to the coral reef ecology but also to the cultivated seaweed species.

Local seaweed species face the similar threat of an infectious type of a disease considering the traditional method of propagating *Eucheuma/Kappaphycus,* since seaweed cultivation started in the Philippines in the late 1960's. The genetic implication of clonal propagation in these seaweeds lies in the tendency of some species to become susceptible to a potential pathogen (Santelices 1992). An "early warning device" in seaweed farming against potential pathogens, such as bacteria, is therefore crucial in the management of seaweed farms. Any approach to this problem would lie on the understanding of the whole seaweed pathosystem in the context of host-pathogen interaction.

There are two important disorders seen in *Eucheuma/Kappaphycus* cultivation that have especially caused problems in recent year. These are:

"Ice-ice" disease. "Ice-ice" is generally caused by unfavorable environmental conditions in the planting site. This is a rather general statement because "unfavorable factors" in the cultivation site refers either to high or low temperature, high or low salinity, high or low light intensity, and also to insufficient nutrient, and so forth. Addressing any of these factors is considered a management intervention strategy. So far, the role of temperature, salinity and light intensity, taken singly was observed in controlled laboratory set up as possible predisposing factors that can lead to "ice-ice" disease. The role of microbial pathogens has also been shown as having to do with "ice-ice". In my own study of the role of bacteria as a lead factor in "ice-ice" disease development, it was discovered that normal (resident) bacteria could become opportunistic pathogens under certain conditions. Subliminal environmental factors (e.g. low salinity, or low light intensity) although in itself may not readily lead to the disease manifestation could predispose the seaweed to bacterial attack, mainly by certain opportunistic pathogens. The seaweed-bacterial pathogen interaction could be akin to those in terrestrial plants. Could it be possible that a highly virulent pathogen is responsible for the wholesale destruction of cultivated seaweed crops in the Philippines? Normally, the surfaces of submerged plants are areas readily colonized by bacteria but only a few strains could be potential pathogens. In the case of *Eucheuma,* two such bacterial pathogens belonging to the *Vibrio-Aeromonas* complex and the *Cytophaga-Flavobacterium* complex demonstrate the seaweed-bacteria interaction (Largo et al. 1995b). Strains of these two groups of bacteria can induce the ice-ice disease in *Eucheuma* when the seaweed plant is subjected to stressful factor of either low

salinity or low light intensity in suboptimal level. While *Cytophaga* sp. P25 showed non-motile behavior, cells of *Vibrio* sp. P11 are active swimmers. This motile behavior of *Vibrio* makes such bacterium an efficient seaweed surface invader. We theorized that it produces hydrolytic enzyme against carrageenan - the compound that makes up the bulk of the cells' interstitial matrices. Indeed *Vibrio* sp. P11 when cultured in a medium of carrageenan instead of agar grows quite well. This ability to digest carrageenan enables the bacterium to penetrate the inner region of the seaweed thallus. I believe that by its lytic activity, it starts digesting epidermal cells, destroying plastids bearing the pigments, hence, the initial bleaching manifestation of the infected part. This leads to gradual hydrolyses of the thallus starting from the cortical layer and into the medulla leading to necrosis (tissue death). There could be other bacteria with similar ability as *Vibrio* sp. P1l that needs to be isolated.

In recent years, many seaweed farms ceased to exist because of the "ice-ice" problem. This has been happening in Bohol, in Batangas, and even in Iloilo. Was it not that widespread "ice-ice" events, if you remember well, took place during the *El Niño* and *La Niña* seasons? What is the probability of "ice-ice" not being caused by microbial pathogens?.

Epiphyte infestation. Epiphytes refer to organisms, small or large, that colonize the surfaces of seaweeds. A serious case of epiphytism has been reported very recently in Calaguas Is., Camarines Norte, and in many parts of the Bicol region. Is this another threat to seaweed farming? Figure 1 shows a common red algal epiphyte, *Polysiphonia* (with dark arrows) and diatoms (broken-line arrow) on *Kappaphycus* thalli. The *Polysiphonia* epiphytes create small, slightly elevated pores on the surface. These pores give "goosebumps" appearance on the thalli surface.

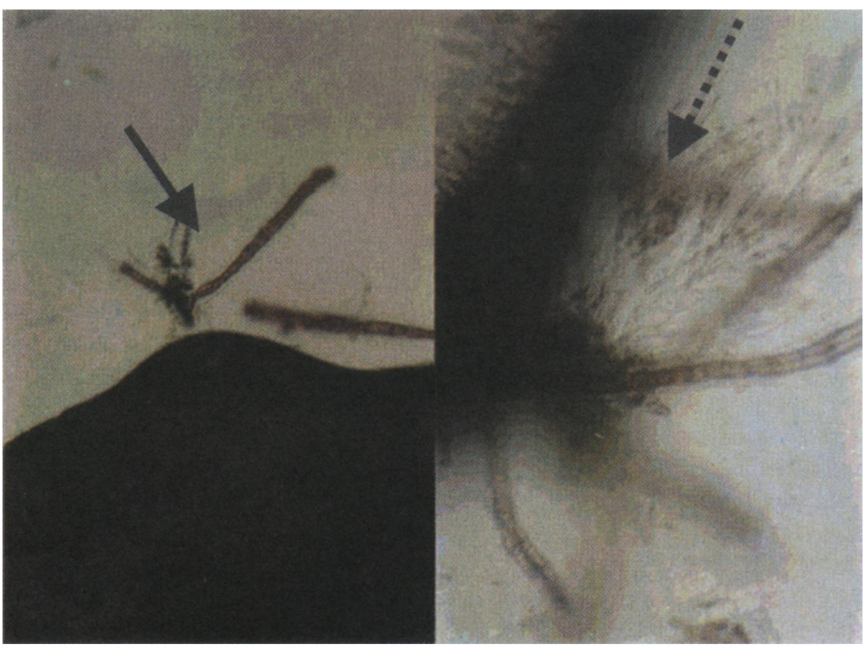

Figure 1. A red algal epiphytes (left away) *Polysiphonia* and diatoms (right away) on *Kappaphycus* thalli.

Microscopic examination of a sectioned thallus (Figure 2) shows that these pores are actually sites of penetration of the epiphytes (with arrows). Whether or not this filamentous alga takes on a more elaborate habit as an endophytic plant will be a subject for future investigation.

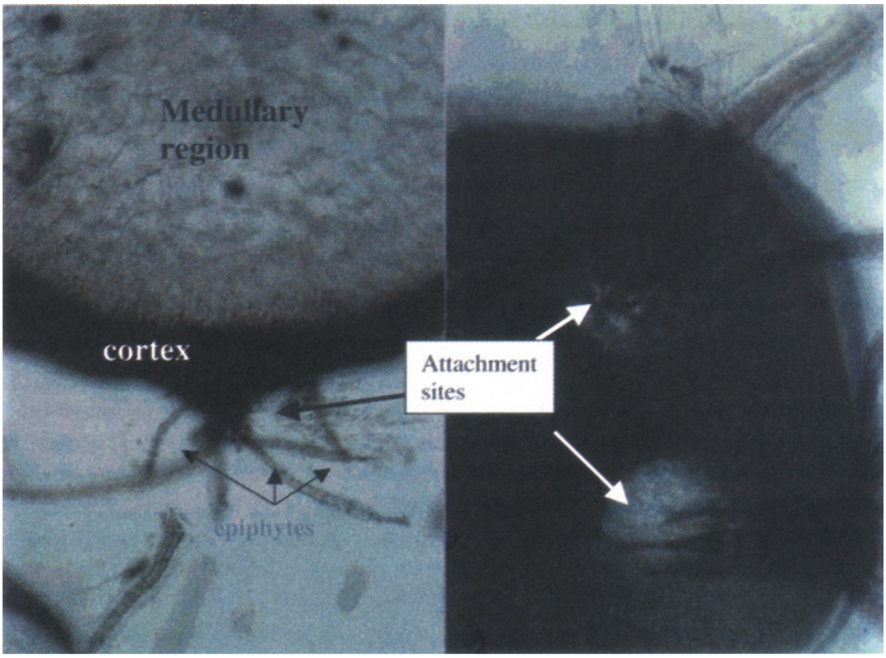

Figure 2. Microscopic examination of sectioned thallus showing actual sites of penetration of the epiphytes, (shown with arrows)

Primary considerations in the diagnosis of disease in seaweeds

Andrews and Goff (1984) recommend that diagnosis, in order to determine symptomatology of a seaweed disease, should not be attempted without familiarity with the algal host affected, preferably by personal experience or, as a minimum, by the study of publications on the growth of the plant and the biotic factors affecting its development. The following needs to be considered:

- the direct or indirect role of environmental factors in disease development;

  that cases in which a primary pathogen is involved such that the disease can be relatively easily diagnosed by symptom (expressions of the host) or signs (visible evidence of the pathogen) will likely be rare;

- that several different diseases may occur concurrently; and

- that visual diagnosis is limited because similar symptoms may result from different agents and, conversely, the same agent (particularly if abiotic) may induce different symptoms in different algae.

It is also important that the suspected organism first satisfies the Koch's postulate to determine whether or not the organism is really a pathogen or not. The following steps are needed to address the Koch's postulate:

- The causal agent must be associated in every case with the disease under natural conditions and, conversely, the disease must not appear in the absence of the agent
- The causal agent must be isolated in pure culture and characterized
- Typical symptoms must develop when the host is inoculated with the agent under suitable conditions, and the appropriate control inoculations be concurrently made
- The causal agent must be re-isolated and demonstrated to be identical to the agent isolated originally

In the case of "ice-ice", the disease may not be necessarily caused by a specific bacterial pathogen. In fact several bacteria, as was shown for *Vibrio* sp. PH and *Cytophaga* sp. P25 can play a trigger role.

Detection of pathogenic organisms

The detection system of a pathogen still relies on the culturability of the organism in an agar medium. Unfortunately, this does not assure the unequivocal proof of association of the suspected pathogen with the host. Biomolecular probe as used in the medical field in detecting disease organisms is yet to be established in seaweed pathology. The potential use of immunology-based techniques has been attempted in seaweeds to detect and monitor the pathogen in the host plant. Direct detection of bacteria, i.e. without agar culture, for instance, has been used to monitor the *Vibrio* sp. P11 in *Kappaphycus alvarezii* (Largo et al. 1998) and in *Gracilaria* species. The method of detection, which utilizes polyclonal antibodies (rendered visible with the use of fluorescent dye such as FITC), was found to be quite effective in establishing the growth behavior of the organism in the thallus. This technique could be made as a practical tool to monitor suspected pathogens. However, it is necessary that the antibodies developed against the target organism should be highly specific and does cross-react with other organisms, either closely or distantly related.

"Ice-ice" disease triggered by bacteria could take place under the following conditions:

- *If there is slow water movement in the cultivation ground.* Some pathogens, especially bacteria, are highly motile and can very easily invade seaweed surfaces. Strong water current, aside from enhancing nutrient exchange, also prevents potential pathogen that comes from the surrounding water from establishing on the seaweed surface (Largo et al. 1997).
- *If the cultivation ground is close to freshwater sources, such as rivers or creeks.* This practically reduces the salinity of the seawater below normal and a stressful factor to the seaweed (Largo et al. 1995a). These places are not the desirable sites for *Eucheuma* farming since it has a normal water salinity requirement of between 33-35 ppt.

- *If water temperature is high, especially if this is accompanied by high light intensity.* This is also stressful to the seaweed. This can be remedied by moving the plants to a slightly deeper location, but not too deep to dampen growth performance. Normal temperature requirement for *Eucheuma* is between 25-31°C.

Although each of the above factors could act independently from each other, they could act synergistically, intensifying the development of "ice-ice" (Largo et al. 1995a). •

Possible management intervention

Crop management will tell us that to optimize production, any crop has to be grown at the plant's optimal growth requirement, with optional external investments on energy. Any factor that tends to deviate from this simple rule will produce bad crop that is below sustainable level.

Some suggestions to properly manage the *Eucheuma* crop:

- Avoid overcrowding plants in cultivation. This renders them susceptible to opportunistic pathogens, like some *Vibrios* and *Cytophagas.* Less crowding of plants also enhances light penetration and therefore to growth.

- Stay within the optimal growth requirements of *Eucheuma.* Drastic changes in salinity and water temperature have to be avoided.

- In times of very high light intensity, as during summer period, especially during *El Niño* seasons it may be advisable to move plants to a deeper location where light intensity does not lead to photoinhibition. Ways to improve planting techniques in such a way that *Eucheuma* crop can be easily moved need to be studied. *El Niño* season is destructive to seaweed cultivation, hence measures to prevent "ice-ice" need to be in place.

- There is a need to identify more "ice-ice" disease-resistant strains of *Eucheuma.* The "sakol" variety of *Kappaphycus alvarezii* seems to have this property. New *Eucheuma* strains from protoplast fusion out of disease-resistant variety are expected to have this desirable characteristic.

Future direction in the study of seaweed diseases

It is clear that seaweed diseases could have a possible effect on seaweed cultivation in the Philippines. Based on our current knowledge of seaweed pathosystem, it is realized that much remains to be pursued in addressing the problems associated with seaweed farming. The following are suggested:

- Research on seaweed diseases and other disorders should be intensified in order to address specific problems related to health management

- The reported phenomenon of intense epiphyte infestation in *Eucheuma* farming (e.g. in Calaguas Island, Camarines Norte) is an emerging problem that needs closer monitoring

- More screenings of potential pathogens based on Koch's postulate should be conducted
- Innovative techniques in the detection of potential pathogens of "ice-ice" should enhance the capability of farmers to monitor possible outbreaks of diseases
- Management strategies in seaweed farming should anchor on sound scientific bases

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